Fermilab

UPC 130

VACUUM PROPOSAL FOR THE INJECTION STRAIGHT SECTION E0

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April 29, 1980

Figure 1 shows the layout of the injection region for the Energy Doubler/Saver. The region contains eight Lambertson septa, four steering dipoles, and a quadrupole, all warm magnets. In addition, two windows separate the Main-Ring vacuum from the ED/S vacuum.

In this report we propose a system of ion pumps (diode type, titanium cathodes) which will result in a pressure of 1×10^{-8} Torr, as required by H. Mizuno, S. Ohnuma, and A. G. Ruggiero in UPC No. 119.

The outgassing rates are based on our measurements on a 3-ft long sample Lambertson which had prebaked laminations (800°C), one post-assembly bake at 400° C and low-temperature bakes (80 to 120° C) after each exposure to air or dry nitrogen. The data of this measurement will be published shortly in UPC No. 122.

These outgassing rates may be expressed either as rates per cm^2 of exposed area (edge area of laminations) or per cm^2 of laminations. Since the test magnet was of dimensions similar to those of the injection septa, both methods will give similar answers. The calculations presented here are based on outgassing rates per cm^2 of exposed edge-on area, which makes it easier to apportion the gas load to channel and exterior respectively.

These input rates are derived from an observed pressure of 4×10^{-9} Torr at 40° C with two Main-Ring type pumps on (60 ℓ/sec total), and an extrapolation to a four times higher pressure at 60°C. For a total exposed edge area of 12,500 cm^2 we get an ougassing rate of 7.2×10^{-11} Torr ℓ/cm^2 sec, which is used in these calculations.

Figure 2 shows the construction of the septa. They consist of a stack of U-shaped laminations containing the coil and a smaller stack of laminations, enclosed in a stainless-steel skin, containing the circulating beam channel (field free) and the extracted beam channel (in the magnet gap). Figure 3 shows the location of six pumpout ports on the outside of the magnet, and the way these ports communicate with the circulating beam channel through gaps in the laminations.

The vacuum requirement mentioned above applies only to the circulating beam channel. It would be advantageous if it were possible to pump on this channel separately from the extracted beam channel and the outside surface of the lamination stack. This is only partly possible because these spaces communicate with each other around the magnet ends to some degree; a common flange between magnets is unavoidable, but we hope to retain some of the benefits by placing 10 of the 13 pumps used for a pair of septa on ports communicating with the circulating beam channel. The remaining 3 pumps will pump both on that channel and the other spaces, since they are located between the magnets and at their ends.

Circulating Beam Channel

Figure 4 shows the proposed pump layout. We work with pumps of a nominal speed of 50 ℓ/sec, pumping through the two "chimneys" shown in Fig. 3. Their combined conductance of 250 ℓ/sec reduces the pumping speed from 50 to 41.6 ℓ/sec.

The conductance of the beam channel between pumpout ports is 45.2 ℓ/sec (for a 3-ft length, see below).

Gas Load on These Pumps

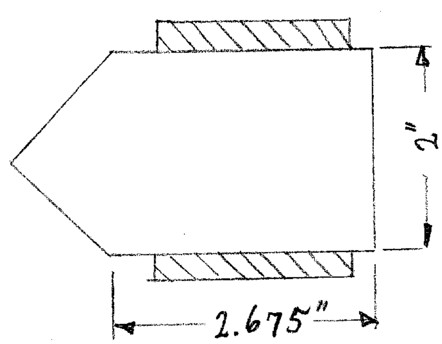
There are two sources of gas: the beam channel section belonging to each pump and approximately one half of the circumference of the stack. We assume the other half of the circumference delivers its gas load to the extraction channel, hence to the magnet ends.

Beam channel circumference: 26 cm
Outside circumference: 86 cm
Gas load per cm: $Q' = dQ/dL$
$= (26\text{ cm} + 86/2\text{ cm})(7.2\times10^{-11}\text{ Torr }\ell/\text{cm}^2\text{ sec}) = 5.0\times10^{-9}\text{ Torr }\ell/\text{sec cm.}$
Gas load per pump: $Q = Q'L = (5.0\times10\text{-}9)(91.4\text{ cm})$
$= 4.6\times10^{-7}\text{ Torr }\ell/\text{sec.}$

With 41.6 ℓ/sec speed we get a pressure of $p = Q/S = 1.1\times10^{-8}$ Torr.

Pressure Bump Between Pumps

$$\langle\Delta p\rangle = \frac{2}{3}\,Q'R'\,\frac{x^2}{2},$$



where Q' as above, $R' = L/F$ (= "resistance/cm") and x is the half-distance between pump ports.

Conductance of the beam channel:

Circumference $B = 25.85$ cm
Area $A = 41\text{ cm}^2$
Conductance $F = 19.4\ A^2/BL$[T/M
$F = 4130/L\ \ell\text{cm/sec}$

$F = 45.2$ P/sec for a 3-ft length with $T = 300$ K, $M = 28$ mass units.

$$R' = \frac{1}{4130} = 2.42\times10^{-4} \text{ sec}/\ell\,\text{cm}.$$

With these numbers we obtain

$$\langle\Delta p\rangle = 2/3\ (5\times10^{-9})(2.42\times10\text{-}4)[(91.4/2)^2/2]$$

$$\langle\Delta p\rangle = 8.4\times10^{-10} \text{ Torr}.$$

The average pressure in the beam channel is the sum of the two:

$$\langle p\rangle = 1.1\times10^{-8} + 8.4\times10^{-10} = 1.2\times10^{-8} \text{ Torr}.$$

Pumps Between Adjacent Lambertsons

The gas load is due to: 3 ft of beam channel × 2 magnets half the outer circumference × half length × 2 magnets.

Gas load due to 3 ft of beam channel: $Q = 4.6\times10^{-7}$ Torr ℓ/sec, as above.

Gas load to half the outer circumference × half length is:

Circumference D = 86 cm.

$$Q = \left(\frac{86}{2}\right)\ (95 \text{ in.} \times 2.54)(7.2\times10^{-11}) = 7.5\times10^{-7} \text{ Torr } \ell/\text{sec}.$$

The total gas load due to two half-magnets is then

$$Q_{pump} = 2(4.6\times10^{-7})(7.5\times10^{-7}) = 2.4\times10^{-6} \text{ Torr } \ell/\text{sec}.$$

With a pump of 200 ℓ/sec the pressure will be 1.2×10^{-8} Torr.

Pumps at the Ends of Lambertson Pairs

If we neglect the gas load from the (well baked) beam pipe, the pump will see half the load calculated above (one magnet only). We suggest using a 200 ℓ/sec pump here also, because this pump will help improve the vacuum in the fairly long stretches of beam pipe, bringing the average pressure to below the design value of 1×10^{-8} Torr.

With a 200 ℓ/sec pump, the pressure at the ends of the magnet pairs will be 6×10^{-9} Torr.

Beam Pipe

The gas load on the beam pipe will be quite small. We suggest using small pumps (25 ℓ/sec) every 6 m like in the Main Ring, yielding a pressure well below 10^{-8} Torr.

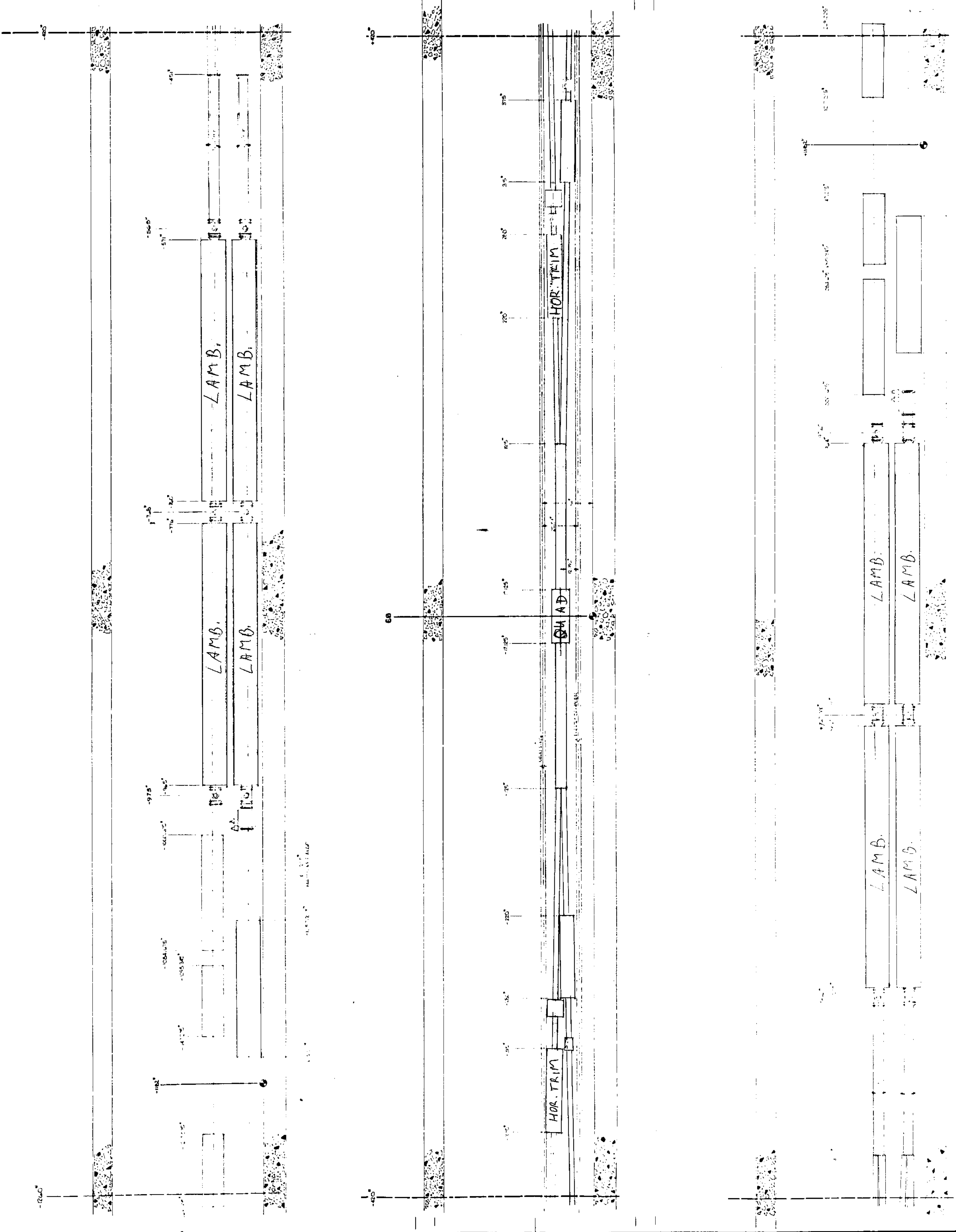

LAMB.
LAMB.
LAMB.
LAMB.
HOR. TRIM
QUAD
HOR. TRIM
LAMB.
LAMB.
LAMB.
LAMB.

Fig. 1

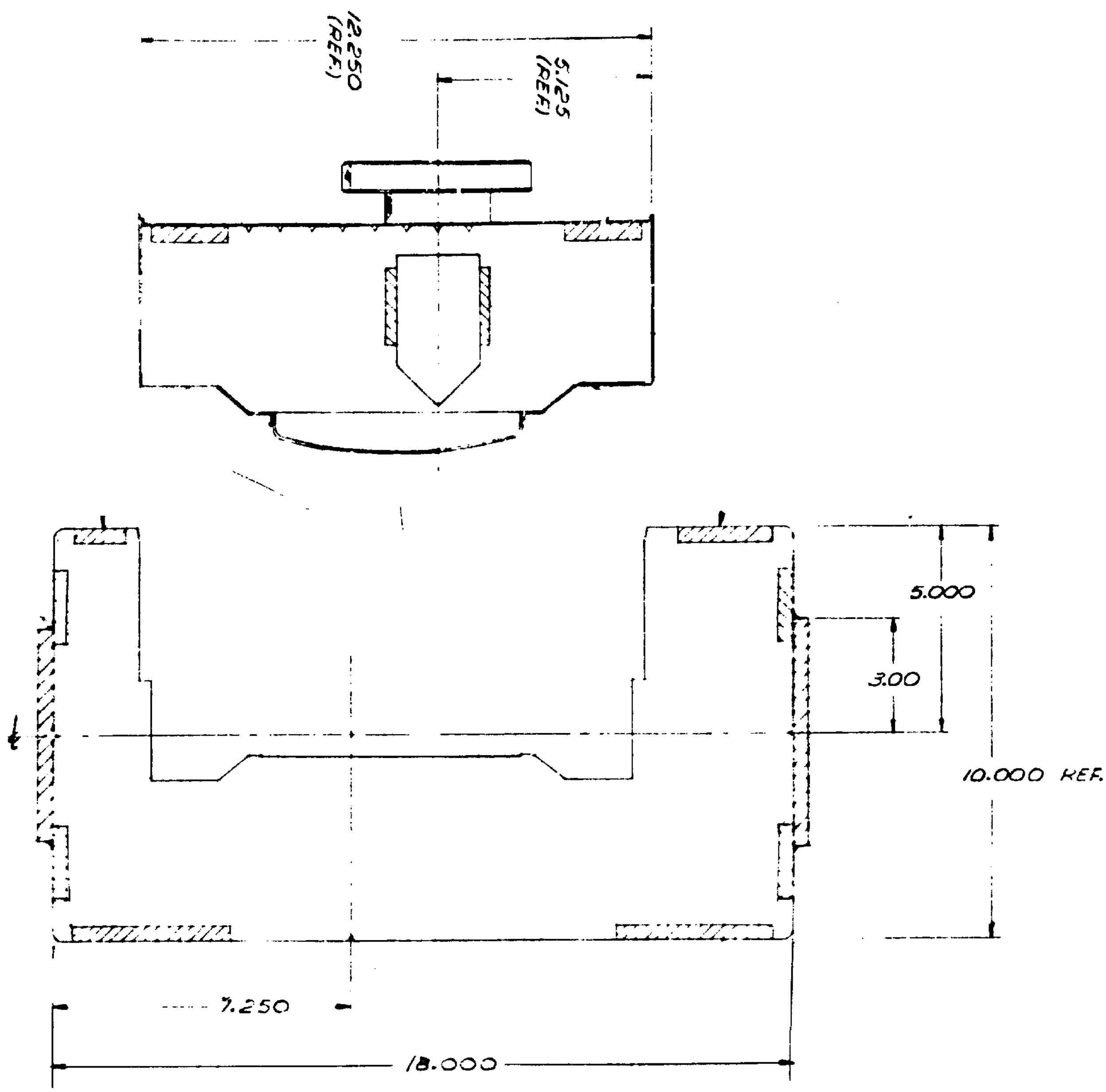


Fig. 2

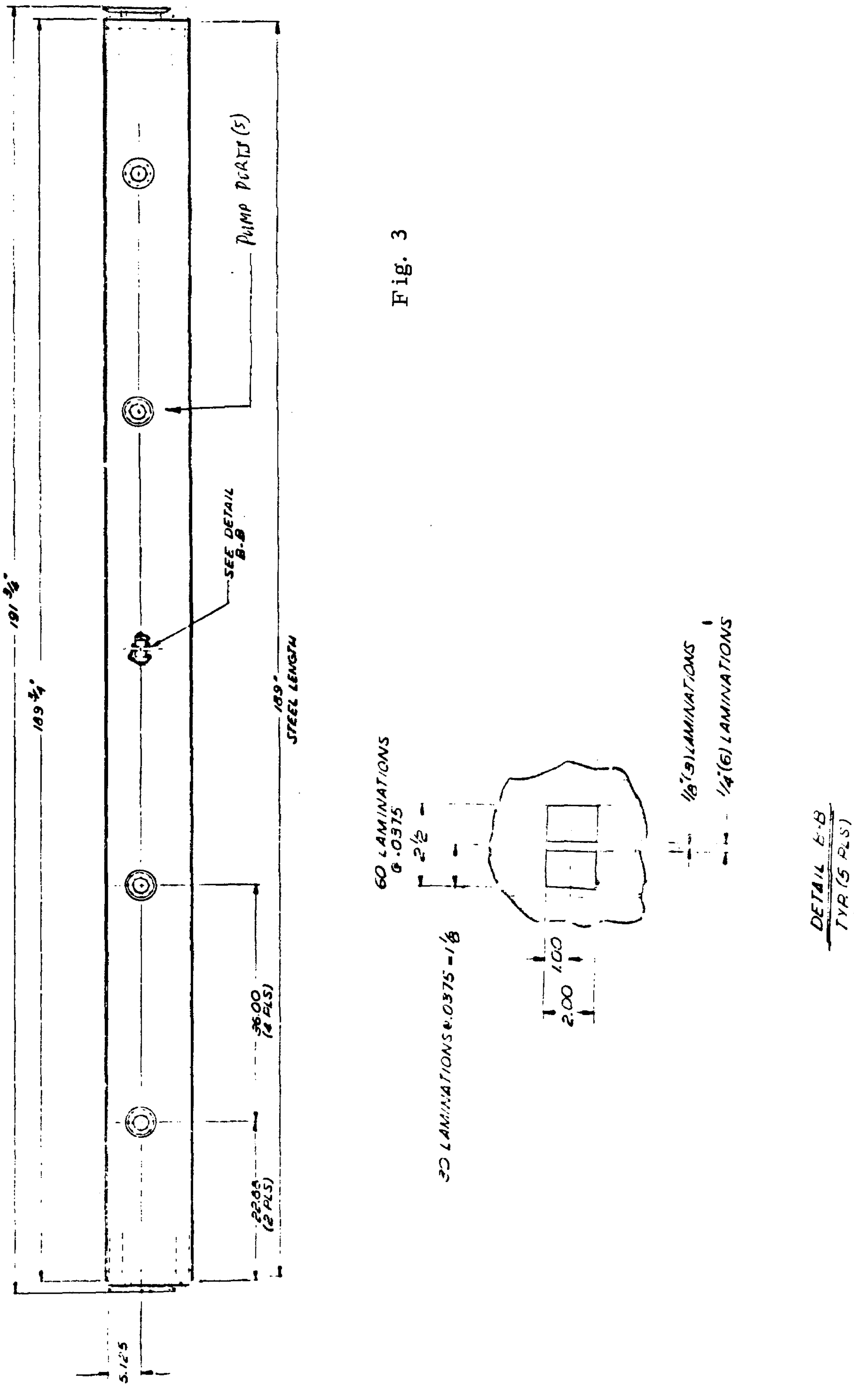
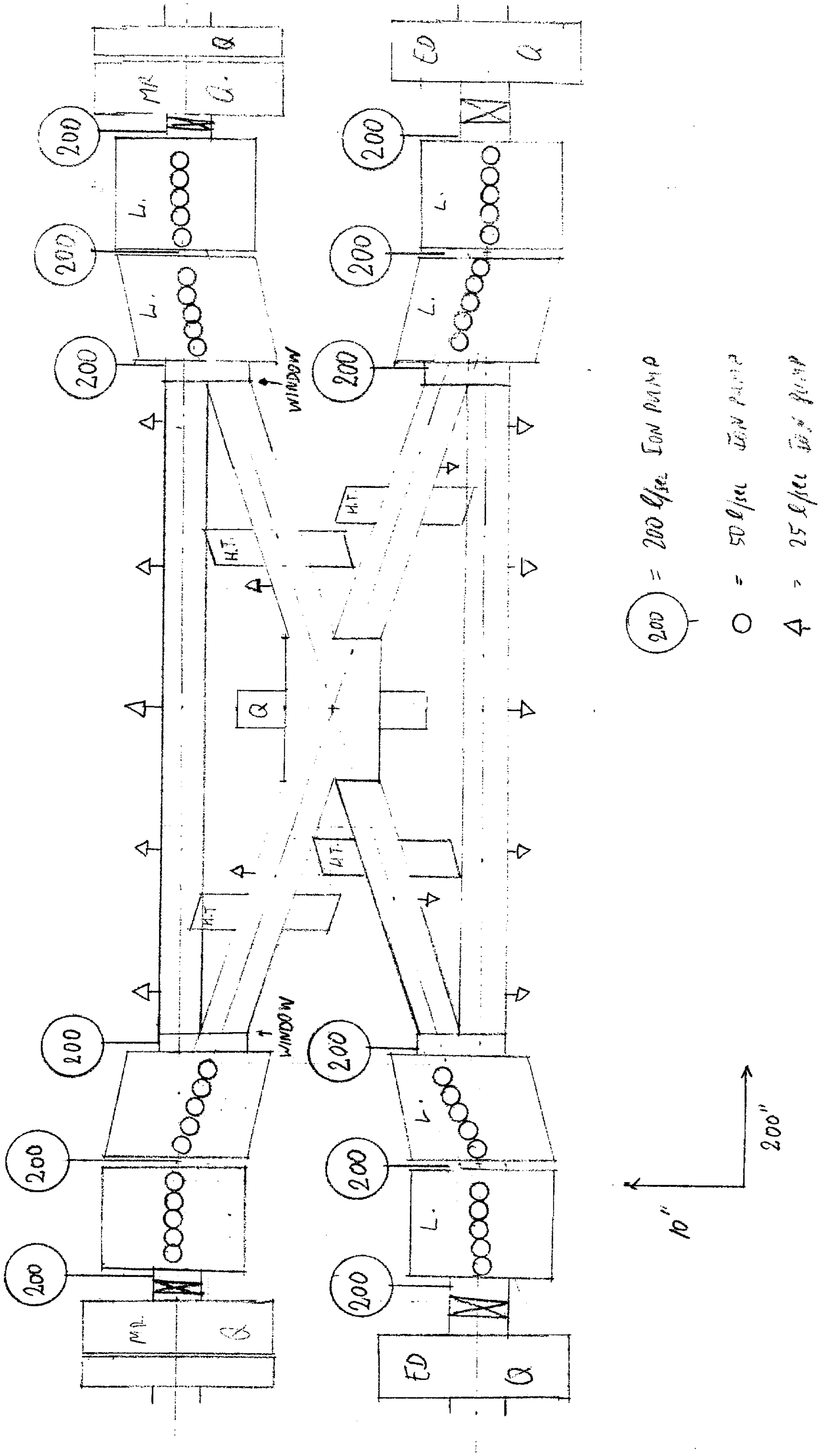

191 3/8"
189 3/4"
189"
STEEL LENGTH
PUMP PORTS (5)
SEE DETAIL B-B
36.00 (4 PLS)
22.83 (2 PLS)
5.125
60 LAMINATIONS @ .0375
2 1/2
30 LAMINATIONS @ .0375 - 1 1/8
1.00
2.00
1/8"(9) LAMINATIONS
1/4"(6) LAMINATIONS
DETAIL B-B
TYP (5 PLS)

Fig. 3



200
L.
MR
Q
ED
H.T.
WINDOW
200 = 200 l/sec Ion Pump
= 50 l/sec Ion Pump
= 25 l/sec Ion Pump
10"
200"

Fig. 4